U. S. DEPARTMENT OF AGRICULTURE.

FARMERS' BULLETIN No. 266.

MANAGEMENT OF SOILS TO CONSERVE MOISTURE,

WITH SPECIAL REFERENCE TO SEMIARID CONDITIONS.

BY

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF SOILS,
Washington, D. C., September 1, 1906.

SIR: I have the honor to transmit herewith, and to recommend for publication as a Farmers' Bulletin, the manuscript of an article on Management of Soils to Conserve Moisture, prepared by Mr. George H. Failyer, of this Bureau. The preparation of this paper was suggested by the increasing interest taken in the question of dry farming in parts of the semiarid West, and is designed to meet the constant inquiries for full information on this important western problem.

Very respectfully,

MILTON WHITNEY,
Chief of Bureau.

Hon. JAMES WILSON,
Secretary of Agriculture.

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MANAGEMENT OF SOILS TO CONSERVE MOISTURE.

MOVEMENT OF WATER IN SOILS.

The greater part of the water that falls as rain passes into the soil. The proportion that runs off without entering the soil varies with the compactness and inclination of the surface and with the character of the rainfall. The water which does enter the soil passes downward, the free or gravitational water which forms visible liquid layers on the soil grains or occurs between them being pulled down by gravity. The water held by the soil particles against the force of gravity is called capillary water. It can not be seen as liquid water, but its presence may be recognized by its effect upon the color of the soil. If in too great quantity to be disposed of by capillarity, the rain water runs down into the lower soil and finally joins the so-called ground water, also called bottom water, or permanent water, raising its level temporarily. In drying weather the capillary water evaporates from the surface of the soil, the soil drawing more water from below, but not in sufficient quantity wholly to replace that lost by evaporation, and there is, therefore, a continual decrease in the content of capillary water until another rainfall. The free or permanent water may rise into the soil as capillary water to replace that lost by evaporation, and it is constantly running out of the soil into the natural drainage channels as spring and seepage waters. These several motions of water all take place when the rainfall is sufficient to give an excess over what the soil can hold in what has been called the capillary state.

If the surface soil be open and loose, heavy rains completely fill the pore spaces of the upper soil. When the pulverized layer is thin, it often becomes so soft and filled with water that this loose layer washes and greatly injures a field.

THE IDEAL TILTH.

It is from capillary water that agricultural plants, for the most part, obtain the water necessary to their growth. In order that they may make their best development, the soil must be in such physical condition that the roots of plants can readily penetrate it and ramify thru it; it must contain sufficient capillary water to supply the needs of

the plants; and this water must be renewed as it is taken up. There should be no large air spaces, since these cause the soil to dry out readily and prevent the development of the many fine branching rootlets necessary to the best development of plants. It is somewhat difficult to describe in words this proper mechanical condition of the soil. It is porous but not loose; firm but not hard nor consolidated; close-grained but not run together nor adhesive. The ideal condition is that of a good loamy soil which has been thoroly pulverized when in best condition as to moisture and has then been firmed by pressure. The pulverizing breaks the soil into granules which the pressure brings close together without destroying them. The soil still has a mealy or crumbly texture. In such a soil the roots of plants make their best development. In such a soil, too, beneficial bacterial life finds its most favorable environment. Such soils will take up and hold the most water, not as water is held in a dish but rather as it is held in a sponge. It is free to move under capillary forces and yet it does not exclude the air, nor interfere with any of the vital, chemical, or physical processes in the soil but is conducive to them. The capillary water in such a soil and the mineral nutrients it contains are readily reached and absorbed by the extending roots of plants.

The soil as a whole is generally drier when the crop matures than it was at seeding time. In this case all the rainfall during the growing season has been lost from the soil by drainage and by evaporation from the soil and from the crop, and some of the water already in the soil at seeding time has likewise been lost. This being true, a condition of soil that will take up the greater proportion of the rainfall and will dispose of it as capillary water is to be desired.

EFFECTS OF TILLAGE.

Proper tillage has two important effects. First, the soil is brought into the desirable condition already described, so that there will be a deep, mellow, but firm seed and root bed to absorb and store the rainfall and to prepare plant food, and, second, the loss of water by evaporation from the soil is prevented as far as possible. The operations of tillage may be considered under two heads—the preparation of the seed bed, and the cultivation of the growing crop. In general, plowing is the most important of the operations in preparing the seed bed, since it is universally applicable; but there are special cases where draining is the first requisite in bringing the soil into condition.

DRAINAGE.

Need of air in the soil.—There are flat lands and heavy clays where a system of tile drains is of more value than any other treatment that can be given them. Such soils hold water within them in a form that

has been designated as free water, or gravitational water—that is, water that is free to move under the influence of gravity. Such a soil acts like a dish or other vessel. There are several disadvantages or injurious consequences resulting from having a soil so filled with water. There can be no circulation of air within the soil. The oxygen of the air is necessary in soils for the direct use of plants. Their roots can not grow and extend into the soil to find water and food constituents except in the presence of oxygen. Seeds can not germinate in the absence of oxygen. Microscopic organisms, which are so essential in properly maintaining the fertility of soils, require oxygen just as higher organisms do. The decay of organic matter in the soil in the presence of oxygen is of such character that its products are usually favorable to plant growth. Nitrates, generally the most important element of plant food, are produced in the presence of free oxygen only.

Disadvantages of wet soils.—The entrance of this essential oxygen of the air into soils is hindered when the pores of the soil are filled with water. Such soils can not be worked until late in the spring, because of being too wet. This delays planting. Wet soils are cold, because the water as well as the soil must be heated, and water warms up much more slowly than soil. The removal of the excess of water by draining permits the heat of the sun to warm the soils earlier to a proper degree for the germination of seeds. Clay soils, when too wet, run together and become plastic and difficultly permeable by water, air, and the roots of plants. When they dry out by the later heat of summer they bake and become hard and cloddy, are difficult to till, and are in every way unsuited for cropping. If they be plowed when too wet they become still more puddled, and it requires protracted weathering to bring them into fair condition again. Moreover, these wet soils, both clays and mucks, often contain noxious substances, which interfere with the growth of the most valuable farm crops. These noxious substances are doubtless mainly organic, but may also be mineral. If the excess of water be removed by drains, these noxious substances are washt out or they are oxidized by the air that finds access to the soil and by the growth of bacteria. Thru the weathering processes that go on in drained soils, they become less plastic and less consolidated, so that drainage becomes more perfect and the friable root bed is deepened. Crops on these drained soils endure drought better than they did before. In the early part of the growing season, while plants are establishing their root systems, the undrained soils are full of water near the surface. Plants can not send their roots into this stagnant water, and hence are shallow rooted. Later, if dry weather comes on, the upper soil dries out, and the roots, being near the surface in this dry upper soil, can not supply sufficient water for the needs of a good crop.

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All heavy and mucky soils are better for being thoroly drained. If not naturally so, whether tiles should be laid or whether open drains will be effective must be determined by inspection in each particular case.

Depth of drains.—Generally the deeper the tiles are placed the more effective and perfect the drainage, and also the more expensive. Drains should, of course, be laid below the frost line and out of the way of all tillage operations. They should be laid by the use of a level, so that there may be no sags or traps in the drain, and the outlet should be such that the water runs freely from the tile.[a]

SUBSOIL PLOWING OF DRAINED LANDS.

Heavy clays that require underdrainage are generally benefited by subsoiling; that is, by breaking up the lower soil without bringing any of it to the surface. This facilitates drainage and adds to its good effects. There are two forms of subsoil plows. The one consists essentially of a curved bar of steel which, when drawn thru the soil, tears it up after the manner of a very large harrow tooth. The other bears a wedgelike shoe on the lower end of the bar. It breaks up the subsoil more than the preceding, but is of heavier draft. The more usual procedure in subsoiling is to turn the surface with a common stirring plow, as in ordinary plowing, and follow in this furrow with the subsoil plow. This loosens the soil to a depth of 18 to 24 inches from the original surface. The next furrow of the stirring plow covers this loosened subsoil, and the subsoil plow is run in the bottom of the new furrow. Sometimes the subsoil plow is used without first turning the surface. In such cases it is not run so deep and its work is less effective.

FIG. 1.—A good form of subsoil plow.

The subsoil is commonly wetter than the surface soil. If a heavy clay, and it is stirred when too wet, it will become more puddled, neutralizing the effects of the plowing. Subsoiling should never be done when the subsoil is wet enough to be plastic and to cake on drying. It may require two or three years after putting in the drains for the subsoil to come into proper condition for plowing. The

[a] Farmers' Bulletin No. 187, U.S. Department of Agriculture, treats quite fully the subject of the drainage of farm lands, giving detailed instructions for performing the work, and, therefore, no special directions for constructing drains will be given here.

subsoiling should be done in a dry time of year, and then only when an actual examination of the subsoil shows it to be in condition to be worked without puddling or forming clods. When the subsoil has been put in the proper condition by the use of the subsoil plow, it will generally be necessary to repeat the operation only once every fifth or sixth year.

SUBSOIL PLOWING OF LANDS NOT DRAINED.

Recognizing the advantages of a deep, fine-grained seed and root bed, one that will absorb and retain a large quantity of water, the use of the subsoil plow has been widely recommended as a means of producing it. Its use for the purpose of deepening the soil reservoir and the feeding ground of the roots of plants is so distinct from that given under the preceding heading, where its object is principally to facilitate drainage, altho it accomplishes more than this, that its value in the one case can be no certain criterion as to its value in the other.

Experience seems to justify the following conclusions regarding the subsoiling of dry fields:

(1) Light sandy soils are not profitably subsoiled. Deep plowing of these will give the necessary condition for absorbing the rainfall, and for the extension of the root systems of plants.

(2) Unless the soil has been settled to firm it and to reestablish capillary connection with the lower soil, yields will frequently be less on subsoiled land than on that surface plowed. Heavy rains will settle the soil and fill it with water so that the effects proper to this preparation may be expected. But until these rains do come, the soil will have had no chance to exert any increased absorbing capacity it may possess, and, being loose and open and disconnected from the lower soil, will dry out more rapidly and completely than a soil not so thoroly broken up. The subsoiling should be done in such season of the year that rains will intervene before seeding time.

(3) If subsoiling be determined upon, it should be in the nature of an experiment to see how it works on the particular soil concerned. If good results follow, the subsoiled area may be extended.

(4) In subsoiling dry fields it will often be better to use a plow with a subsoiling attachment, running it a few inches below the bottom of the furrow, gradually attaining the desired depth by plowing deeper year after year. In this way the soil will never be so much disturbed, and treatment for "packing" and "firming" it will be more effective. It will also be less expensive to prepare the soil in this way than to run a regular subsoiler 12 to 18 inches deep in the bottom of the furrows. But it will, of course, take a longer time to secure the deep soil reservoir.

PLOWING.

Plowing is the most usual method of fining the soil for planting; draining and subsoiling, when required, are preliminary preparations. When soil is well drained, either naturally or artificially, plowing is all that is required to bring it into shape. There is more or less difference in character between the upper or surface soil and the subsoil. Farming operations affect the former, and from it plants draw their nourishment in large part. It is a distinct advantage to have this cultivated soil or tilth as deep as it can reasonably be made. But in its natural state a comparatively thin layer only of the soil has been perfectly weathered and made in good condition to support plants. Where the soil is a clay or is underlain at a depth of 6 or 8 inches by a heavy clay subsoil, it will generally be found advisable to plow not more than 1 or 2 inches deeper than the soil has been previously plowed. By exposure and weathering the subsoil acquires the character of surface soil. In this way any desired depth of tilth may be produced without injury to crops. On open soils the dangers of deep plowing are not so great, but even here deep plowing should be done some time before the crop is put in. The soil will then have time to weather somewhat, and to settle and establish capillary connection with the soil below. This latter point is of importance, and will be considered more fully on a later page.

The sod plow.—There are two distinct styles of moldboard plows. They differ in shape, and hence in their effects upon the soil turned by them. One may be called the sod plow, the share or cutting edge of which is generally longer and makes a more acute angle with the bar or landside than in the case of the other style.

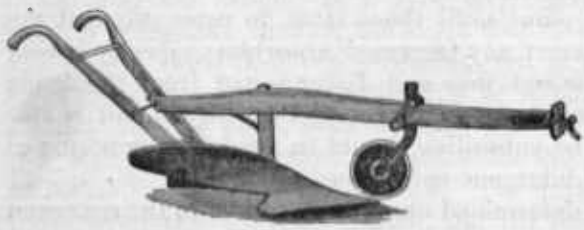

FIG. 2.—Type of sod plow.

The moldboard has a gradual turn, inverting the furrow as a whole, but causing little motion within the furrow slice. Thus the soil is not pulverized very much. Such a plow is quite serviceable in plowing sod; the furrow being placed flat, the grass dies readily and the roots rot rapidly. By the use of the disk and the harrow such rotted sod may be worked up into a fairly good seed bed. If sod ground be plowed while the grass is in active growth, the sod rots more rapidly and the ground comes into condition sooner than if the plowing be done in a season when the plants are dormant. Raw prairie sod requires a year or more to come into really good tilth, even if the breaking be done when the growth of the grass is most vigorous. This applies with most

force to grasses having hard tough roots, such as the blue stem of the western prairies. Tame grass sod comes into condition sooner.

The stirring plow.—In the other form of plow the moldboard is shorter and has a steep upward curve, so that the soil is not only inverted but is pulverized by the shearing motion within the furrow slice. When a loam or a sandy soil is in proper condition of moisture no better tool for pulverizing it could be desired than a good plow of this latter form. If heavy clay soil must be plowed when wet, the sod form of plow will probably be preferable, since it disturbs the soil less and will not render it so cloddy. But if naturally hard soils have become dry they will be broken up more thoroly by the steeper moldboard. Such soils should be plowed when in the process of drying they have lost their plasticity, but have not yet formed clods. All soils should be handled with discriminating judgment, but heavy clay soils require the greater care to secure the best results from the work put upon them. The experienced farmer readily recognizes the condition each particular type of soil must be in to be put in good tilth by plowing, but he does not always realize the advantage of doing the work at the right time.

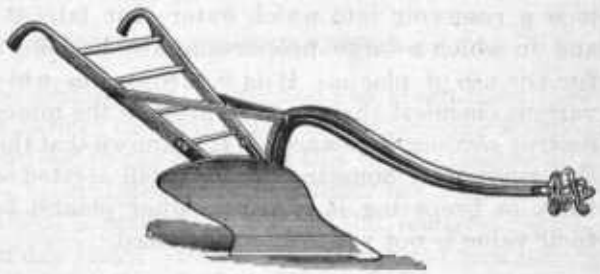

FIG. 3.—Type of stirring plow.

Means of preventing "plow sole."—With these moldboard plows the smooth bottom of the furrow makes a distinct plane of separation between the soil that has been turned and that below. It is desirable to reestablish connection between these in order that excess of water from rains may readily sink into the ground, and that the water in the subsoil may rise by capillary action to reach plant roots occupying the upper soil. If this furrow bottom could have a rough or broken surface, capillary connection could be more readily established. In this respect the disk plow should be better, altho it does not pulverize the soil so well. It is quite serviceable on hard, gummy soil also. It would appear to be of especial use in humid regions where a hardpan or plow sole has formed at the depth the ground has been plowed. This hardpan has been formed in part by the action of the common plow itself. It separates the furrow by cutting, and the sliding of the plow over the flat and plastic furrow bottom puddles it, making a smooth, hard surface at the depth plowed. At successive plowings the plow runs at this depth, increasing the hardness and thickness of the pan. If the furrow slice were broken off instead of being cut off by the wedge-shaped plow the hardpan would not so

readily form. The disk plow breaks off the furrow slice as described, and it may with profit be used occasionally to destroy this hardpan by cutting down into it and thus breaking it up. In fact the pan might be prevented from forming by the use of the disk plow every few years, running it quite deep.

A deep seed bed.—By draining and subsoiling when necessary, and by deep plowing as has been described, a deep and pulverulent seed and root bed may be prepared. It is more than might be implied by these terms; it is a reservoir into which water that falls as rain will readily sink and in which a large proportion will be held in the best condition for the use of plants. It is a medium in which will take place the various chemical changes that prepare the mineral food of plants and destroy noxious substances. It is known that the innumerable bacteria that make their home in a mellow, well-aerated soil perform important work in preparing it for the higher plants; but it is probable that their value is not yet fully appreciated.

WHEN GROUND SHOULD BE PLOWED.

For some crops the soil may be plowed immediately before planting and good results will be secured. This is true of corn. Wheat, on the other hand, especially winter wheat, requires a firm soil into which to send its roots, and plowing should not precede seeding by too short an interval. The soil should have time to settle before seeding. Heavy rains settle the soil, but since drier weather prevails in early autumn there is danger that the plowed soil will not thoroly settle. When wheat or other fall crops are to follow a crop which is harvested in early or middle summer, and the ground is to be plowed for the wheat, the plowing should be done as soon after harvest as the condition of the farm work will permit, and the ground should then be smoothed with a harrow to reduce evaporation of the soil moisture.

Weeds use large quantities of water. Aside from other ill effects they may have, much of their injury to crops in which they grow is due to their appropriating the soil water. Where water is of any agricultural value weeds should never be allowed to grow. If stubble ground be left to grow up in weeds it dries out excessively. The early plowing urged above kills weeds and prepares the ground to absorb any rains that come, and the freshly plowed and harrowed soil will not lose water so rapidly as the stubble ground.

If land is to be planted in the spring late fall plowing has certain advantages. It may be done after the removal of a late-maturing crop. If the subsoil be turned up in the fall the freezing and thawing and general weathering will improve it. If rough as left by the plow the soil will absorb rains and melting snows and will crumble down into good condition and will not be so likely to run together as if smoothed by the harrow. Such fall-plowed ground will generally be in good

shape for small grain seeded in the spring. The disk may be used if necessary. If corn is to be grown on fall-plowed land it should be thoroly disked and harrowed unless the corn be planted with the lister. In case there be heavy rains before corn-planting time heavy soils will run together and cake. The disk run over these as soon as the surface has dried sufficiently will keep them in condition. In general, the disk should be used if there be a considerable interval between plowing and planting. In using the disk, lap half way to level the surface.

LISTING GROUND, AND THE LISTER.

The lister consists essentially of a right-hand and a left-hand plow joined at the bar. It throws the soil out each way, leaving an open furrow. The corn is drilled in the bottom of this furrow, either by a drill attachment or by a separate drill. The lister has been successfully used in the section of country just east of the semiarid region. It is most successful in dry years. In wet years the listed corn suffers

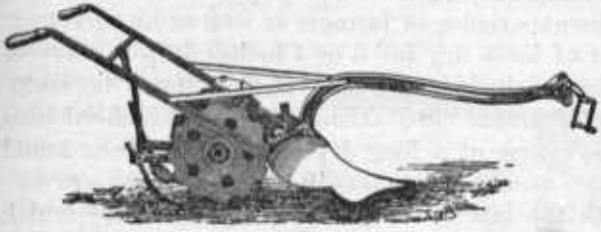

FIG. 4.—Lister with drill attached.

FIG. 5.—Sketch showing two moldboards of lister.

on rolling ground from the washing in the furrows, and from water standing in the furrows on level ground.

Corn plants put out their roots near the surface of the soil, regardless of the depth at which the seed has been planted. The corn planted in the furrow roots near the top of the soil in the bottom of the furrow. The first cultivation is given with a spike-tooth harrow as soon as weeds start on the tops of the ridges. This rolls a little fine soil down into the furrows. Later tillage works more of the soil into the furrows, until they are finally filled and the ground is level. The root system having been established in the bottom of the listed furrow, the subsequent filling of the furrows places these roots several inches deeper than they would have been had the ground been plowed in the ordinary way and the planting been done on a level surface.

This plan works well in the drier portions of the humid regions. While listed corn stands drought better than that planted on level plowed ground, it may be doubted whether it will do so well in the more humid portions of the country. The washing and the standing of water in the listed rows, already mentioned, may be sufficient to overbalance any advantage derived from its greater resistance to drought.

Since the seed is planted in the bottom of the freshly made furrow, the soil here is not so warm as the surface soil, and listing should not be done until the soil is sufficiently warm. This will be about the usual seeding time for level-planted ground.

CULTIVATION TO RETAIN MOISTURE IN THE SOIL.

If the soil reservoir has been well prepared and rains have filled it with capillary water, tillage should be directed to reducing the loss of water by evaporation to the lowest possible point. The water that passes thru the plants themselves is of benefit to the crop; that evaporating directly from the soil is wholly lost. In spite of all that can be done there will be losses from the soil in drying weather, but these may be materially reduced.

A loose soil with large pores has low capillary power and will absorb but little water from a moist soil in contact with it; therefore a layer of such loose soil covering the moist-soil reservoir will conserve the water in the latter by diminishing direct evaporation from it. It is well established by the experience of farmers as well as by direct experiments that a layer of loose dry soil 3 or 4 inches deep is effective in preventing the excessive drying of soils. If this mulch be maintained thru the season by proper cultivation, it is more beneficial than a straw mulch. In the course of a long dry period it has been found to conserve the moisture as well as a straw mulch, and there are several disadvantages with the latter. If put on early, the straw mulch keeps the surface soil wet in the spring and early summer. This makes the soil cold, excludes the air, and causes plants to root near the surface. When this surface soil dries out, these roots can not supply water and the crop suffers. The soil mulch and the cultivation to produce it cause the plants to root deeply, the aeration of the soil is improved, and in all respects the effects of the dust mulch are good. To be most effective the surface tillage must be kept up. The soil must be cultivated after each rain of sufficient amount to puddle the surface—that is, cause it to run together and form a crust on drying.

Experience has shown that the rapid and complete drying of the surface which ensues in some portions of the semiarid region forms a mulch which serves to reduce evaporation from the deeper soil. In some cases it has been claimed to be as effective as that produced by tillage, but it is less certain and should not be relied on. Therefore in dry farming in the West, as well as in farming under humid conditions, tillage to produce and maintain a dust mulch should be the universal practise. In a dry time it will pay to run a small-tooth cultivator thru the corn, altho it be later in the season than corn is usually cultivated and the plants are so tall that the double cultivator can not be used. If the soil has been kept loose on top the

plants will have rooted below the dust mulch and the late culture of the surface will not injure them. It will aid in retaining moisture, will facilitate the aeration of the soil, and increase the activities of desirable micro-organisms.

It is usual to speak of a "dust mulch," but the better mulch has a granular structure and is not composed of dust. In open countries the dust would blow off, to the detriment of the soil, and a dust surface would not absorb the rainfall so readily as that composed of very small lumps of soil.

Tools used in cultivation.—The implements employed in cultivation will vary somewhat with the crop and with its stage of growth. Tillage of ground before the crop is up and when the plants are very small, especially listed crops, should be with the spike-tooth harrow with the teeth set at a considerable slant. Weeds are most easily destroyed when they are coming up. The harrow is very useful for this purpose, and at the same time it produces the soil mulch. A distinct advantage in the use of the harrow is the rapidity with which the ground may be gone over. The spike-tooth harrow, or the disk harrow followed by the spike-tooth harrow, should also be used in summer culture intended to conserve moisture for a future crop.[a] When the plants are too large to be cultivated with the harrow, any of the modern double cultivators will do good work in cultivating corn and similar crops; but when equipped with gangs of three to five narrow shovels that throw the soil but little, they are still more efficient for surface cultivation, unless the ground has become weedy from inability to cultivate it because of wet weather. Bladelike shovels that run nearly horizontal and cut off a thin layer of soil are effective unless there be too much trash. These blades can be so adjusted that the soil will pass over them, forming a loose layer, which on drying will protect the moist soil below.

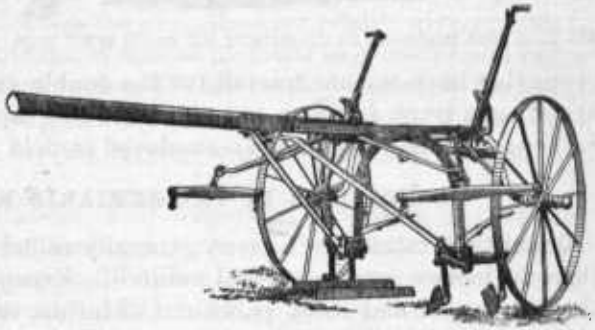

FIG. 6.—Double cultivator equipped with bladelike shovels for surface cultivation.

In cultivating the soil as thoroly and frequently as the best farming requires, the labor will be excessive unless tools be used that enable a man to cover a large area in a day. Plenty of team power should be available on a modern farm, and three or four good horses to one driver are more economical than two when the land is such that

[a] For account of "summer culture" see later sections on semiarid region.

large tools can be successfully operated. Farming with one horse to a man is poor economy and will absolutely prevent the good farming necessary to conserve the soil moisture.

The disk harrow and the spike-tooth harrow have already been suggested for certain kinds of work. No better tools need be desired for the work for which they are designed. They are made in sizes for 2 horses and for 4 horses. In using the disk harrow it should be lapt half-way in order to leave a level surface. Disks 14 to 16 inches in diameter do better work than those of greater diameter, but the draft is heavier. Except in special cases, double cultivators, or two-row cultivators, should be used. Single cultivators are useful in cultivating crops that have become too tall for the double cultivator and in small areas, as in truck farming, but no tool of less capacity than the double cultivator should be generally employed in field work.

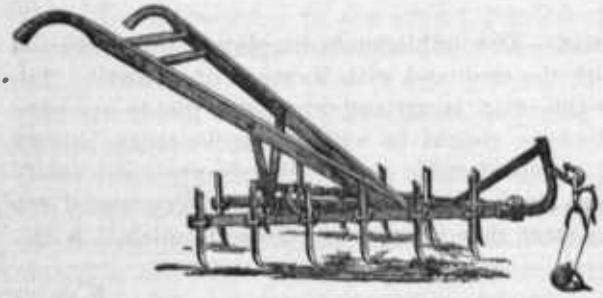

FIG. 7.—A good implement for maintaining soil mulch in tall crops.

CONDITIONS IN THE SEMIARID REGIONS.

Quantity of rainfall.—Regions generally called semiarid receive less than 20 inches average annual rainfall. Excepting limited areas in the Northwest and some parts of California, this includes the whole region west of the ninety-ninth or one hundredth meridian. In Nevada and California are limited areas with such low rainfall as to be truly arid. In the Intermountain valleys the precipitation for the most part is during the winter months. In the Plains region the greater part of the annual rainfall is during the spring and summer months.

Absorptive power of the soil.—Speaking broadly and comparing large areas, it has been estimated that 50 per cent of the rainfall in humid regions runs off in the streams. A portion of this consists of flood waters which run off the surface and do not enter the soil, but a large part is subterranean water that finds its way to the creeks and streams from the lower depths of the soil. Estimating in the same way, it is believed that about 10 per cent of the rainfall of the Plains region runs off in the streams. For the most part this consists of storm waters. There are few springs, and the streams generally cease running soon after rains. If the rainfall be 18 inches and the run-off be 10 per cent, about 16 inches of rain will have entered the soil. However, in some portions of the semiarid regions and during some years in any portion, the rainfall may be no more than 10 or 12 inches.

For the most part the soils of the Plains region are loams of exceptional fertility, when sufficiently watered. The 16 inches of water absorbed would saturate these soils with capillary water to a depth of 5 or 6 feet if none were lost between rains by evaporation. The rains moisten the surface to a depth depending, of course, upon the amount of rainfall, but the moisture is always confined to a few feet of the surface soil. It is during exceptionally wet seasons only that dry soil can not be found at a depth of 3 or 4 feet. The conditions are so different here from those in humid climates that it is difficult fully to realize them and their bearing upon farm practise.

Water is not readily taken up by dry soil, but if the surfaces of soil particles be already covered with thin films of moisture, water added to the soil will thicken these films. If a film becomes very much thicker than that on neighboring soil particles, a portion of the water passes to the new particle, and so on, tending to equalize the distribution of water over the grains of soil, the size of grains and gravity influencing the final condition of equilibrium. When the liquid layer is reduced to a certain thickness the grain does not readily give up water. A condition favoring the use of special methods to conserve soil moisture exists in the Plains region. With its dry undersoil the water can not readily sink deeply into the soil and escape in a downward direction. It remains for the farmer to prevent its loss by evaporation into the air.

Character of rains.—There is an important difference in character between the rains of the East and those of the West. The summer rains of the West, and especially of the Plains country, consist largely of infrequent heavy showers. If the soil be open and deep, this rain sinks deeply into the ground. As previously mentioned, the hot sun and drying winds of the semiarid regions rapidly dry the topsoil, and this forms a mulch, or covering, which retards evaporation. Light showers in a dry time do very little good. They wet the surface, and if the water extends to the moist soil below, water from below actually flows to the surface over the wet soil grains, and the water of the light shower, as well as some of that previously in the soil, is lost by evaporating into the air. In humid countries, where much of the precipitation consists of frequent light, slow-falling rains, with much cloudy weather, the surface dries more slowly, giving less protection to the lower soil, so that much more water is lost from the soil as a whole than would be the case if the same quantity of water came in less frequent rains, provided, of course, the heavy rains all soak into the soil.

SOIL MANAGEMENT UNDER IRRIGATION.

Conditions in the semiarid regions differ so much from those in humid regions that special attention should be called to them; but, where water is available for irrigation, methods of handling soils

may be much the same in the two regions. It is important that irrigation water should be made to go as far in crop production as possible. Systems of farming that increase the duty of water so that a greater acreage can be irrigated with present supplies are of the greatest value to the irrigation farmer. The deep bed of finely granular but well-firmed soil to absorb and hold the water applied, and the surface cultivation to conserve the moisture, are more important under irrigation than in humid climates. Light soils consisting largely of sand and gravel may be made more retentive of moisture by the admixture of organic matter, and loams and heavy soils may be improved by thoro and deep plowing. After soils have been irrigated the surface dries rapidly and frequently forms an objectionable crust. Therefore special care should be taken so to cultivate them as to break up the crust while it is forming. If the work be done at the right time a granular mulch will be produced. Heavy soils require very careful handling after irrigation in order to leave them in good condition.

SOIL MANAGEMENT IN DRY FARMING.

The farming operations in the semiarid sections of the country have generally been of the roughest kind. The effort has been to grow a broad acreage of crops. In good seasons the profits have been large; in dry years the losses were not considered to be so great as if better farming had been practised. But some few farmers have followed better methods, and have shown that the benefits resulting from good farming, as compared with poor farming, are even greater under semiarid conditions than under humid conditions. Good farming not only gives better yields in good seasons, but often secures fair yields when poor farming gives absolutely nothing.

It is not to be expected in the semiarid regions that any method of farming without irrigation will insure crops in all years. There will be years of such light rainfall or of rainfall so poorly distributed that the best system rigorously applied will not prevent crop failures. But by proper soil management and farm management the disastrous years may be rendered less frequent.

Successful management of soils under semiarid conditions requires that thought and effort be directed to accomplish these three things:

1. The collection within the soil of all water falling upon it.
2. The retention within the soil of the water it has absorbed.
3. The growth of crops that thrive well under semiarid conditions.

STORING WATER IN SOILS OF THE SEMIARID REGIONS.

A deep bed of porous soil.—In dry farming (farming without irrigation) in the semiarid regions the quantity of water available to plants is the limiting condition of success. Land is abundant and cheap and the soil is fertile. Water is the one element that may be needed to

produce a crop. Such being the case, it is obvious that no water should be allowed to run off from farm lands. It should all be made to enter the soil. The rains of the semiarid regions, as has been said, often come in the form of sudden and heavy showers. Such rains fill the upper soil completely. The pore space becomes full of water, and unless the lower soil permits the excess to move down rapidly much of the subsequent rainfall runs over the surface and off the fields. This loss of water and accompanying injury by washing is greater as the surface of the field is steeper. In the Plains region the lands are generally level, and in this respect every opportunity is given the farmer to save the water. To enable the water to run down quickly into the lower soil, a deep bed of porous soil should be prepared. This does not mean that the soil should necessarily be loose and open with large air spaces. It should be a mellow, close-grained mass, without any tendency to solidify or to stick together. When the soil is in the condition described by saying it is in *good tilth*, it will take up water readily. This layer of fine, close-grained soil should be deep, in order that much water may be stored in it. Water occupying the interstitial spaces in this upper soil will slowly sink into the deeper soil. Thus, when the soil is properly prepared, the water of a heavy rain may be collected and held as in a sponge-like reservoir. It will sink down so as to equalize itself and leave the soil in good condition for surface tillage and for the development of plant roots. The tilth should be deepened gradually in semiarid regions as well as in humid ones, altho less injury will result from turning up the better-weathered subsoil of the former.

Subsurface packing.—In the process of plowing, the furrow slice is completely separated from the soil below. Trash of various kinds is often turned under, further separating the two. This loosened soil should be settled to reestablish connection with the lower soil. Rains will do the work in time, and in humid regions this may be all that is required, but in semiarid regions it is not. Evaporation is rapid from such loosened soil, and it should not be left in this open condition where water is so valuable. A process of settling and firming the lower soil while leaving the immediate surface loose and granular has been called subsurface packing. This packing may be done with an implement especially devised for the purpose, or less effectively with a weighted disk harrow, setting the disks straight so as to cut down into the soil and turn it as little as possible. A corrugated roller or a spike-tooth harrow also serves to settle the soil when other tools are not available. If much trash has been plowed under or the furrow slice is thick the harrow will be less effective. The common smooth roller by compacting the surface increases the loss of water by evaporation. The ground plowed in the forenoon should be packed and harrowed before stopping work for noon, and the same at night.

This is very important, as a fresh moist surface loses water to the air very rapidly. The surface loosened by the harrow dries out quickly and protects the soil below. If the soil becomes too dry before the harrow is used a fine dust will be the result and winds will carry much of the latter away.

When seed bed should be prepared.—The time when the seed bed is prepared is of importance. It will vary with the nature of the cropping of the land. With wheat, oats, or any crop that is harvested in the summer, the ground should be stirred as soon after the removal of the crop as possible. In this case more will depend upon the time of doing the work than upon the kind of tillage. Owing to the crowding of work at harvest time some rapid way of breaking up the surface should be adopted so that the whole of the field may be gone over quickly. Double-disk the ground and follow with a smoothing harrow. Keep the harrowing close up to the disking. By performing this work early the moisture in the soil will be retained and the plowing may be done more at leisure, but it should not be postponed too long. Plowing will leave such fields in much better tilth than those not so disked. Any rains that come previously to plowing will be taken up by the disked land better than by the dry stubble ground. After plowing pack or settle the soil by one of the methods already given and surface with the harrow. Should the plowing be delayed too long after the disking, and especially should heavy showers intervene, stir the surface of the soil with the harrow. This should be done as soon after the rain as the soil is in a condition not to puddle. After the ground is plowed use the harrow as frequently as is necessary to maintain the mulch 2 or 3 inches deep. Continue this until seeding time.

If the previous crop was harvested in the fall, a forage crop, for instance, the double-disking may be done before the ground freezes. If this has not been done, it should be done as early in the spring as the surface is dry enough. Unless there have been late snows or early rains, disk the ground as soon as the frost is out. The crop to be grown will, of course, determine the time of plowing. If fall wheat is to be grown, the plowing need not be done until late spring or early summer if the surface tillage be kept up. Plow not later than midsummer, pack and harrow as directed for the wheat stubble. In all cases of fall seeding, summer tillage with harrow or disk should be continued so as to maintain the soil mulch.

Advantage of summer culture.—The treatment of soil outlined above has been called summer culture by some. While quite similar to the old custom of summer fallowing, it is something more than that. In the fallow the land was plowed to keep down the weeds and to aerate it. The culture was not specially timed to conserve moisture nor of a special character adapted to that purpose. The culture here described

will give all the benefit of the summer fallow and at the same time save the moisture. It should be pointed out, however, that in regions of high wind some types of soil will not permit of constant stirring, which causes the loosened surface to drift. Such soils are not as well suited to dry farming as more stable types, especially where intertillage crops are to be grown, or where the surface is left unprotected.

Listing.—Whether listing such crops as corn, Kafir corn, sorghum, and cowpeas will be better in semiarid farming than level culture can hardly be said with certainty. All depends on whether more is gained by having the plants more deeply rooted than is lost by greater evaporation from the uneven surface. It must be remembered that the ridges are soon worked down so that the greater evaporation is for a short time and in the cooler weather of the spring, while the deep root system exists thru the whole growing period. It would therefore appear probable that listing these cultivated crops is the better practise in the semiarid regions, as well as farther east where there is more rain, and experience where it has been tried sustains this view. The listing should be done in the moist seed bed prepared the previous year, as already directed. The soil should be firmly prest about the seed by a wheel following the drill.

FREQUENCY OF CROPPING LAND UNDER SEMIARID CONDITIONS.

In several of the Western States many of the farmers are successfully following a system by which they raise a wheat crop once in two years, storing up water in alternate years. Where the rainfall is somewhat greater a crop is grown two out of three years. The system is perfectly flexible, and should be adopted quite generally in the semiarid region.

Plow and cultivate the land as directed for storing and retaining moisture in the soil. If at seeding time the soil is in a moist condition to a considerable depth, put the crop in, even if a crop was grown on the same ground the preceding season. If sufficient moisture has not been stored in the soil, let the land lie over and continue the tillage. The work on the whole will be less than if a crop be attempted each year and the crop will be greater. Indeed, by saving the rainfall of one year to help out the next year, a profitable crop will often be secured when there would have been nothing had an attempt been made to grow a crop each year.

In the mountain States, where the rains largely come in the winter, there is little trouble to conserve moisture sufficient to produce a crop of winter wheat. In the Plains region it is more difficult, for the falls and winters are the dry portion of the year. If there be a deep, moist seed bed in the fall, the crop will generally succeed by the aid of the spring and early summer rains, but if the condition of the

soil is not right, do not attempt a fall crop. Let the land lie over and grow a spring crop, or cultivate during the next summer and seed to fall wheat.

Since corn is not so exhaustive of soil water as is wheat, by thoro and late cultivation of the corn a crop of wheat may be secured after corn, when wheat after wheat would fail. Along the border between the humid and the arid regions an alternation of corn and small grain is the most profitable system. In this case, as in others, the condition of the soil at seeding time should determine whether an attempt be made to grow the wheat crop. If the ground has been kept in good condition, disking the corn ground preparatory to seeding is better than to plow it. Such late plowing would make the soil too loose for wheat. The seed should be planted in the firm, moist soil below the dust mulch. The shoe drill or press drill will do this work satisfactorily. This alternation system should be varied sufficiently to allow an occasional leguminous crop to restore nitrogenous compounds to the soil.

CROPS FOR THE SEMIARID REGIONS.

Plants have habits of growth, and these extend to their minute structures, thus affecting their relations to their environments. These habits or characteristics are partly acquired thru climatic influences. Plants adapt themselves to their surroundings, but this change of habit requires many generations. In dry farming the seed used should be from plants that have been grown in a dry climate. No seed should be purchased without knowing its history. If this does not show the adaptability of this particular seed to the climate where the crop is to be grown, on no account should it be used. Seed produced in humid regions or on irrigated fields should not be used in semiarid farming—only that from dry farms.

The following suggestions are made as aids in selecting crops rather than as absolute guides. Even were the latter desirable, much additional information would be necessary before attempting it.

Live stock.—While wheat will always be a tempting crop in this section, because it is a ready-money crop, and a large acreage can be handled by the use of machinery, stock raising should form an important element in all Plains farming. Rough feed can be grown in even the driest years if moisture has been kept over by summer tillage the previous year. This will not always be true of grain crops. With stock the labor is well distributed thru the year. The manure will be a valuable addition to the land if plowed under and the soil packed some time before seeding the ground. Moreover, stock may be considered a money crop.

Wheat.—The best fall wheat now grown in the dry West is the Turkey Red. It is a hardy sort, standing the climate well and making

a fair yield of hard wheat. A strain of this wheat, more recently introduced, seems to be superior to that generally grown. This strain has received a different name—Kharkov. These wheats come from Russian Asia, a semiarid country.

The Durum wheats, introduced by the Department of Agriculture, are good spring sorts. They likewise are from dry climates. Some of them have given good spring crops in portions of the dry West, and there are indications that valuable fall varieties will develop from some of these Durum wheats.

Corn.—Corn may be grown especially for the fodder, with the grain as an adjunct in favorable years; but by cropping alternate years grain should be secured frequently. It requires less water to produce a pound of dry matter of corn plant than of wheat, and the continued tillage of the corn will conserve the moisture of the soil. But, since an average crop of corn weighs more per acre than one of wheat, the chances of the two with equal rainfall properly distributed will be about the same. The periods of growth of these crops differ, and the distribution of the rains may be such as to favor the one or the other. A small early maturing corn should be selected. There will be greater yield of grain to the weight of stocks than with the larger kinds, and less water will be required. The writer believes that a flint corn gives most promise; this is true of one grown under arid conditions, if such can be secured.

Kafir corn.—This is perhaps the surest feed crop in dry farming. The plant stands drought well and responds to rain at any time before it is killed by frost or a dry soil. If the soil has been properly handled by summer fallowing, a fodder crop will be assured, and a seed crop if there be the usual rainfall. The seed is a valuable feeding stuff, but should be ground or soaked for most kinds of stock, since the hardness of the grain causes much of it to escape mastication and digestion. The white-seeded, black-hulled Kafir has met with most favor. Kafir is a nonsaccharine sorghum. Altho the stalks are not sweet they are quite leafy and afford considerable fodder.

Sorghum.—The varieties generally called sorghum are the saccharine kinds. The sorghums withstand drought well, and are valuable feeding stuffs for both semiarid and humid sections of the country. Like Kafir corn, they may be grown for hay by drilling like wheat, or for grain and fodder by cultivating like corn. The sugar in the stalks increases their value, and the crop should be cut when the seed begins to ripen and cured to prevent loss by fermentation of the juices of the cane after freezing, as happens when pastured off in the fields. There are several good varieties of sorghum, among which may be mentioned Early Amber, Kansas Orange, and Coleman.

Alfalfa.—Alfalfa will be a valuable crop for the semiarid region if sufficient moisture can be secured to sustain the plant from two to four years. It should at first be tried in any particular section and on

any particular soil on an experimental scale. The success of this trial will show whether it is wise to extend the area; the experience of neighboring farmers should always be considered. Be sure to have a good store of water in the soil and the latter in good condition, a firm, fine-grained, deep seed bed with a soil mulch protecting it. With a moist seed bed brought over from the previous year seeding should be done in early spring, as soon as danger of severe frost is past. The plants will get the start of the weeds and grass and become well rooted before the summer heat. In humid regions late summer or early fall sowing is most successful; but in the semiarid districts this late seeding does not generally do so well, owing to the dry falls and winters. Under no consideration should alfalfa be seeded with a so-called nurse crop. Give it all the moisture in the soil—it will pay; a better, more even stand will be secured and the plants will be better established and more able to withstand a dry fall and winter. Certain alfalfas coming from a dry country seem to give promise for the Plains.

In Utah semiarid farming, where the greater part of the annual rainfall comes in the winter season, it has been found advisable to make hay of the first alfalfa crop and let the second crop make seed. The moist soil of the spring favors the development of foliage, while drier conditions are more favorable for the production of seed. The rainfall being mainly in the later spring and the summer months in the Plains region, it will frequently happen that because of delayed spring rains the first alfalfa crop should be permitted to seed. If rains come later, a hay crop may be secured. Whether it is wiser to make hay of the first crop or to let it seed can be determined by the season, the moisture condition of the soil, and the size of the alfalfa at the time of blooming. If a good crop of hay has grown at cutting time, make hay of it. If the crop is light and the soil dry when the plants begin to bloom, a crop of seed may be produced and the alfalfa should be allowed to stand to mature the seed. One hay crop and a good seed crop per year is very profitable.

Rate of seeding.—In order to make the most of the moisture in the soil, the stand of the several crops must not be too thick. Even in humid farming the stand of corn and the several grains is often so thick that the growth of the stalks exhausts the moisture of the soil or they crowd each other and the yield of grain is lessened. Two good stalks of corn with one good ear each are better than five or six stalks with nubbins, and many of the stalks without even these. In dry farming it is especially necessary to guard against thick seeding. One-half the quantity of seed usual in humid farming is enough, and some very successful farmers claim the rate of planting should not be more than one-third that usual in the humid sections of the East.

It has been customary in humid regions to use 20 or more pounds of alfalfa seed per acre. If the seed be planted in a well-prepared seed

bed that is full of moisture, 10 to 15 pounds are ample. In semiarid regions 6 to 8 pounds of good alfalfa seed properly put in will give a sufficient stand.

One-half bushel to 3 pecks of wheat drilled in soil prepared as directed will give a better yield of fall grain one year with another in dry farming than if the usual 1 or 1¼ bushels be planted. The plants will more readily find moisture, and if conditions are favorable they will tiller or stool out and give a really stronger stand because of the better-rooted plants. While spring-sown crops do not tiller so much as fall crops, and therefore require more seed per acre than the latter, the same rule applies. For the several spring crops use about one-half the seed usually sown in humid regions.

If corn be planted in rows 4 feet apart and the seed be drilled one grain every 2 feet and it all germinates, it will give a stand of corn that will tax the soil moisture in all but unusually wet years. Experience may show that if grain be the object of the crop the stalks should be 2½ to 3 feet apart in the row. However, when corn, Kafir corn, and sorghum are grown for rough feed rather than for grain, these should be planted about as is usual farther east when the object is to secure grain. The land will support about twice as many stalks of sorghum or Kafir corn as of corn. When drilled in for hay, it is usual in humid regions to use 1 bushel of seed per acre. One-half bushel to 3 pecks will be about the proper rate in dry farming.

ORGANIC MATTER AND THE CONSERVATION OF MOISTURE.

The organic matter in soils increases their water-holding power and improves their physical condition. This is one of the direct advantages resulting from the incorporation of humus in soils. The organic matter of soils is used up by oxidation during tillage and the soils become out of condition and run together and cake after heavy rains, unless this loss be made good. Organic matter may be increased in soils in several ways. It may be applied in the form of barnyard manure, straw, stalks, etc., and by green manuring—that is, by plowing a green, growing crop under for the special purpose of improving the soil.

Barnyard manure.—Barnyard manure is the most valuable form of organic matter to add to soils, because it is rich as a fertilizer. For this reason the production and proper care of barnyard manure is just as necessary in farming as the growing of the staple crop. One of the great needs of some important agricultural sections is a great increase in live stock to produce manure and make possible the growing of a greater variety of crops, such as are required in an intelligent rotation.

Coarse litter.—Where corn is the principal crop the stalks are generally cut as fodder; if not, they should never be burned, but should be cut and turned under; if fed to stock, the manure should be put upon the fields. Too often straw stacks are burned or permitted to rot down, and the various kinds of vegetable matter about the farm are burned or allowed to waste in outlots. It should all be added to the soil. The mechanical condition of the soil is improved by its decomposition, bacterial life prepares plant food from it, and by giving these agents a suitable home it would be valuable even if this were its only benefit.

In semiarid farming wheat is often cut with a header. The straw left on the ground should be completely covered in plowing and the soil packed to facilitate the rotting of the straw. Until the straw decays it will have an injurious effect, causing the soil to dry out more rapidly; but by cropping alternate years there should be no harm from this cause.

Green manuring.—When plants are plowed under green, they decompose more rapidly than cured plants do. The crop should not be allowed to stand until it has exhausted the soil moisture. If left too long the soil will be cloddy, the plants will not rot well in the dry soil, and the soil may be too dry for a subsequent crop to get a good start. The ground should not be seeded until the material has decomposed.

The crop grown for green manuring will depend largely on the main object to be attained. If the principal consideration be to add organic matter without regard to its nitrogen content some quick-growing plant with heavy foliage should be selected. Oats, rye, sorghum, and even corn sown or drilled, are good crops to produce humus. The sorghum and the corn should be seeded close so as to make a large mass of vegetable matter and still not have large stalks.

Leguminous crops.—Not only does the humus content of soils decrease during cultivation, but the nitrogen content does also. It will therefore generally be profitable to grow for green manuring a crop that adds this element to the soil. Leguminous crops, such as beans, peas, clover, and alfalfa, use atmospheric nitrogen thru the medium of bacteria infesting the root tubercles, while grain crops can not use it, but must get their nitrogen from the soil itself. A leguminous crop used for green manuring will add both humus and nitrogen to soils. The crop selected will vary with the climate. In the northern portions of the humid regions clover has been used as a nitrogen-gathering crop and is well suited for green manuring. Cowpeas have served the same purpose in the South. In the subhumid region cowpeas and alfalfa give good results. In semiarid sections alfalfa will be the best crop for the purpose if sufficient moisture to sustain the crop for a few years can be secured. An annual crop, however, will

generally be most successful as a nitrogen gatherer. Cowpeas are a promising crop for this purpose, as they stand drought well. Cured as hay they make good feed, if the crop can not be spared for green manure, and the stubble and roots by their decay add both nitrogen and humus to the soil. It is a common practise in the South to plant cowpeas between the corn rows when the last cultivation is given the corn. The long season and the moist climate mature a crop of peas from this planting. During unusually wet seasons the same practise might be followed in the semiarid regions, letting the land lie idle the next year and giving it thoro summer tillage. However, the corn and the peas together may require so much water that each would interfere with the other. The plan should be first tried on an experimental scale only.

When wheat is grown in alternate years, advantage may be taken of an unusually wet summer to grow a green-manure crop after the wheat is harvested. Immediately after harvest put the crop, cowpeas, in the stubble ground after having thoroly disked it. Plow the crop under just before killing frost and pack and settle the soil. Give it thoro summer tillage the next season and plant to wheat the following fall.

By taking advantage of seasons and conditions of cropping, the organic matter and the nitrogen of soils may be maintained without serious hindrance to the system of cropping, whatever that may be. But plans should be made so that each field may bear a nitrogen-gathering crop every few years. Cultivated crops should also form a part of the system for each field. They do not deplete the soil of moisture as small-grain crops do. Wheat after wheat keeps the soil continuously drier than corn after corn, or even an alternation of corn and wheat.

The desirable succession of crops can be best secured by adopting definite rotations. The particular crops must be determined upon by local conditions, but the system or rotation must include legumes, cultivated crops or fallow, and grain crops.

SUMMARY.

A deep soil of good tilth will absorb and hold for the use of plants a large part of the rainfall. Such soil is in good condition for the growth of common crops.

Soils can be put in the best of tilth, when in proper state of moisture, by deep plowing, disking, and harrowing.

Evaporation from soils can be lessened by covering them with mulch. The best mulch and the only practicable one on a large scale is a soil mulch. This can be produced and maintained by surface cultivation. To be most effective, the cultivation must be repeated after

rains that puddle the surface soil. To reduce the labor of frequent cultivation, implements that cover a large surface may be employed.

In semiarid regions special effort should be made to utilize the rainfall. The ground should be plowed soon after the removal of a previous crop; it should then be settled and smoothed. By frequent cultivation of fallow land, moisture may be stored for a crop the next year. In this way crops have been grown in semiarid regions once in two years when crops every year on the same land have failed.

In dry climates the corn crop succeeds better when put in with the lister. It roots deeper, stands up better, and the work in growing a crop is less than when planted in level-plowed soil.

Strains of plants that have originated or been grown for many years in dry climates should be selected for the semiarid regions, and the rate of seeding should not be more than one-half that common in humid regions. Stronger, better-rooted, and more hardy plants will thus result.

Organic matter should be maintained in soils to improve their physical condition. This may be accomplished by green manuring, and by the plowing-in of manure, straw, stalks, and other vegetable refuse.

Leguminous crops, such as clover, alfalfa, and cowpeas, used as green manure, not only increase the humus of soils but supply nitrogen from the air. This is the cheapest way of adding this important fertilizer ingredient.

Anyone who proposes to begin farming without irrigation in a region of light rainfall should be properly cautious. He should not be misled by glowing accounts of large crops; he should investigate carefully the possibilities of the particular region in which he expects to settle; he should have clearly in mind beforehand the kind of crop which he will produce, and he should not undertake dry farming if a failure of crops at the beginning will mean to him complete and permanent disaster. It should be clearly understood that farming in the semiarid regions, without irrigation, can not in the nature of things be as certain or as profitable as farming under favorable conditions in the humid regions.